

WHAT IS CLAIMED IS:

- 1 1. An assembly comprising:
 - 2 an actuator with a longitudinal axis having a fixed end, and a free end
 - 3 configured to translate in three orthogonal directions with respect to said fixed end;
 - 4 a multiple bar linkage having first and second links mutually constrained to
 - 5 translate with respect to each other, and wherein said first link is fixed to a reference
 - 6 structure and said second link is constrained to translate in a direction generally parallel to
 - 7 the longitudinal axis of said actuator; and
 - 8 a sample holder supported by said linkage; and
 - 9 a coupling having first and second ends, said first end being fixed to said
 - 10 actuator proximate to its free end, and said second end being fixed to said second link, the
 - 11 coupling adapted to transmit displacement in a direction substantially parallel to the
 - 12 longitudinal axis of said actuator.
- 1 2. The assembly of claim 1, wherein said actuator has a z-axis translating
- 2 section, and an x and y-axis translating section disposed between said fixed end and said z-
- 3 axis translating section.
- 1 3. The assembly of claim 2, wherein said reference structure is mechanically
- 2 independent from translation of said z-axis translating section but mechanically responsive to
- 3 said x and y-axis translating section.
- 1 4. The assembly of claim 3, wherein said reference structure is fixed to said
- 2 multiple bar linkage to deflect said multiple bar linkage in X and Y directions in response to
- 3 X and Y deflections of said x and y-axis translating stage.
- 1 5. The assembly of claim 4, wherein said multi-bar linkage further includes a
- 2 first mirror fixed to at least one of said links of the multi-bar linkage, and a second mirror
- 3 fixed to another of said links of said multi-bar linkage.

1 6. The assembly of claim 5, wherein the assembly is adapted to be supported in a
2 chassis, and further wherein said first mirror is disposed in the path of a light beam from a
3 light source mounted on said chassis and is disposed to reflect the light toward said second
4 mirror.

1 7. The assembly of claim 1, wherein the metrology apparatus is a scanning probe
2 microscope.

1 8. The assembly of claim 1, wherein said actuator is a piezoelectric actuator.

1 9. In an assembly for a metrology apparatus having a probe assembly, the
2 assembly including an elongate actuator with a longitudinal axis and having a first end
3 configured to be coupled to a frame of the microscope and a free end configured to be
4 coupled to a sample holder, wherein the actuator is configured to provide controllable
5 translation in three orthogonal directions upon application of proper electrical stimuli, a
6 method of reducing positioning errors at the free end of the actuator comprising the steps of:

7 fixing the probe assembly to the frame;

8 supporting the sample holder with a reference structure of the metrology
9 apparatus, the reference structure being substantially insensitive to longitudinal expansion or
10 contraction of a first portion of the actuator;

11 isolating the reference structure from a longitudinal deflection of the first
12 portion of the actuator;

13 driving the first portion of the actuator;

14 simultaneously generating both longitudinal deflections as well as lateral
15 deflections in the first portion as a result of said driving step; and

16 preventing the lateral deflections generated in the first portion of the actuator
17 from laterally deflecting the sample holder while simultaneously transmitting the longitudinal
18 deflections to the sample holder.

1

1 10. The method of claim 9, wherein a second portion of the actuator is configured
2 to provide translation in a plane substantially perpendicular to the longitudinal direction, and
3 wherein the method further includes the steps of:

4 driving the second portion of the actuator;

5 generating lateral deflections in the second portion as a result of said driving
6 the second portion step; and

7 transmitting the lateral deflections in the second portion to the sample holder.

1 11. A scanning probe microscope assembly, comprising:

2 a microscope frame;

3 a piezoelectric actuator having a first end fixed to said frame and a second free
4 end coupled to a sample holder;

5 a first reflector assembly fixed proximate to said free end of said piezoelectric
6 actuator;

7 a first electromagnetic radiation source fixed with respect to said frame and
8 disposed to direct radiation onto said first reflector assembly; and

9 a first electromagnetic radiation detector disposed to receive light from said
10 first source after it has been received and reflected by said first reflector assembly and to
11 generate a signal indicative of a degree of longitudinal deflection of said piezoelectric
12 actuator.

1 12. The scanning probe microscope assembly of claim 11, further comprising a
2 cantilevered probe having a free end and a fixed end and coupled at its fixed end to said
3 frame,

4 said probe including a second reflector disposed to translate with said probe when
5 said probe is deflected with respect to said piezoelectric actuator.

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1 13. The scanning probe microscope assembly of claim 12, further comprising a
2 second electromagnetic radiation detector disposed to receive light reflected from said
3 second reflector and to generate a signal indicative of a degree of deflection of said free end
4 of said probe with respect to said fixed end of the probe.

1 14. An apparatus for measuring movement of an actuator in a metrology
2 apparatus, the measuring apparatus comprising:

3 a sample holder coupled to the actuator;

4 an optical measuring device including a light source that generates a light
5 beam, said measuring device being configured to change the direction of said beam in
6 response to movement of the actuator; and

7 a sensor to detect said beam and generate a signal indicative of the movement
8 of the actuator.

1 15. The apparatus of claim 14, wherein said measuring device includes a movable
2 bar assembly coupled to the actuator and to a reference structure, wherein said bar assembly
3 has a reflecting surface that is adapted to deflect said beam, and wherein said bar assembly is
4 responsive to movement of the actuator so as to change the direction of said deflected beam.

1 16. The apparatus of claim 15, wherein said bar assembly includes a first link
2 having a first end coupled to the actuator, and a second link defining said reflecting surface
3 and having a first opposed end rotatably coupled to said first link and a second opposed end
4 rotatably attached to said reference structure.

1 17. The apparatus of claim 15, wherein said reference structure is tubular and
2 generally surrounds the actuator.

1 18. The apparatus of claim 17, wherein said reference structure is configured to
2 allow said light beam to pass therethrough.

1 19. The apparatus of claim 15, wherein said bar assembly includes a link having
2 opposed ends, a first opposed end rotatably coupled to the actuator and a second opposed end
3 rotatably coupled to said reference structure.

1 20. The apparatus of claim 15, wherein said bar assembly comprises a four bar
2 linkage including first and second reflecting surfaces, said surfaces disposed to reflect light
3 such that the incoming and outgoing beams are generally parallel.

1 21. The apparatus of claim 14, wherein said optical measuring device includes a
2 lens disposed intermediate said light source and said sensor.

1 22. The apparatus of claim 21, wherein said lens has a magnification equal to $1 +$
2 i/o , wherein “i” equals the orthogonal distance between said lens and said sensor, and “o”
3 equals the orthogonal distance between said lens and said light source.

1 23. The apparatus of claim 21, wherein said light source is mounted to the
2 actuator.

1 24. The apparatus of claim 23, wherein said lens has a magnification equal to i/o ,
2 wherein “i” equals the orthogonal distance between said lens and said sensor, and “o” equals
3 the orthogonal distance between said lens and said light source.

1 25. A method for measuring movement of an actuator in a metrology apparatus,
2 the method comprising:

3 providing a movable bar assembly coupled to the actuator and to a reference
4 structure;

5 supporting a sample holder with the movable bar assembly; and

6 measuring, in response to movement of the actuator, movement of said movable bar
7 assembly, wherein the movement of said movable bar assembly is indicative of movement of
8 the actuator.

1 26. The method of claim 25, wherein said movable bar assembly includes a first
2 link having a first end coupled to the actuator, and a second link defining said reflecting
3 surface and having a first opposed end rotatably coupled to said first link and a second
4 opposed end rotatably attached to said reference structure.

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- 1 27. In a metrology apparatus having an actuator for moving a sample in a
2 particular direction, a reference assembly that generally decouples movement of the
3 apparatus in a direction other than the particular direction from the sample, the reference
4 assembly comprising:
- 5 a reference structure;
- 6 a sample holder coupled to said reference structure and to the actuator, the sample
7 being attached to said sample holder; and
- 8 a flexible bar having opposed ends, one of which is coupled to the actuator and the
9 other of which is coupled to said sample holder via a movement isolating device, wherein
10 said flexible bar and said reference structure, are adapted to collectively decouple movement
11 of the actuator in the direction other than the particular direction from the sample.
- 1 28. The apparatus of claim 27, wherein said reference structure is a tubular frame
2 and has a longitudinal axis that is generally collinear with the longitudinal axis of the
3 actuator.
- 1 29. The apparatus of claim 27, wherein said flexible bar is more flexible in
2 response to displacements applied thereto in any direction other than the particular direction.
- 1 30. The apparatus according to claim 29, wherein the particular direction is the Z
2 direction.
- 3 31. The apparatus according to claim 27, wherein said movement isolating device
4 is a parallelogram flexure.
- 1 32. The apparatus of claim 31, wherein said probe structure assembly comprises a
2 four bar linkage having four joints.
- 1 33. The apparatus of claim 27, wherein said movement isolating device is a
2 flexible disc, said flexible disc being attached to said reference structure generally around a
3 perimeter of said flexible disc.

- 1 34. A metrology apparatus for analyzing a sample, the assembly comprising:
2 an actuator including a first actuator stage configured to controllably move in
3 first and second orthogonal directions, and a second actuator stage adjacent to the first
4 actuator stage and configured to controllably move in a third direction orthogonal to the first
5 and second orthogonal directions;
6 a reference structure having first and second ends wherein the first end is
7 fixed relative to movement of the second actuator stage;
8 a coupling coupled to the second actuator stage and to a multi-bar linkage
9 assembly fixed to the second end of the reference structure, wherein the second actuator
10 stage and the coupling are configured to move the linkage in the third orthogonal direction in
11 a manner that substantially isolates the linkage from any second actuator stage motion in the
12 first and second directions;
13 an objective fixed to the reference structure, wherein the objective is between
14 a light source and a position sensor, and the position sensor measures first actuator stage
15 motion in the first and second directions; and
16 wherein the multi-bar linkage supports the sample.
- 1 35. The assembly of claim 34, wherein first actuator stage motion in the first and
2 second directions is coupled to the reference structure.
- 1 36. The assembly of claim 35, wherein motion of the reference structure in the
2 first and second directions is translated to the objective.
- 1 37. The assembly of claim 36, wherein the light source and the position sensor are
2 stationary.
- 1 38. The assembly of claim 34, wherein the position sensor is a lateral effect
2 photodiode.
- 1 39. The assembly of claim 34, wherein the objective further comprises a set of
2 microlenses.

1 40. The assembly of claim 39, wherein the set of microlenses provide optical
2 magnification to increase a signal-to-noise ratio.

1 41. The assembly of claim 40, wherein the magnification is

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$$M = 1 + i/o$$

3 wherein i is an orthogonal distance from the set of microlenses to the position
4 sensor and o is an orthogonal distance from the set of microlenses to the light source.

1 42. The assembly of claim 34, wherein the reference structure and the coupling
2 provide a rigid mechanical connection between the first actuator stage and the sample in the
3 first and second directions.

1 43. The assembly of claim 34, wherein the reference structure further comprises
2 an inside surface adjacent to the actuator and an outside surface.

1 44. The assembly of claim 43, wherein the objective is mounted on the outside
2 surface of the reference structure.

1 45. An assembly comprising:

2 an actuator with a longitudinal axis having a fixed end and a free end
3 configured to translate a sample coupled thereto in three orthogonal directions with respect to
4 the fixed end;

5 a multiple bar linkage having first and second links mutually constrained to
6 translate with respect to each other, and wherein the first link is fixed to a reference structure
7 and the second link is constrained to translate in a direction generally parallel to the
8 longitudinal axis of the actuator;

9 a coupling having first and second ends, the first end being fixed to the
10 actuator proximate to its free end, and the second end being fixed to the second link, the
11 coupling adapted to transmit displacement in a direction substantially parallel to the
12 longitudinal axis of the actuator; and

13 an objective fixed to the reference structure, wherein the objective is between
14 a light source and a position sensor, and the position sensor measures displacement of the
15 objective in a direction generally perpendicular to the longitudinal axis of the actuator.

1 46. An optical apparatus for measuring movement of an actuator in a metrology
2 apparatus, the optical measuring apparatus comprising:

3 an objective fixed to a reference structure coupled to the actuator;

4 a light source that generates a light beam, wherein the optical measuring
5 apparatus changes the direction of the beam in response to movement of the objective;

6 a position sensor that detects the beam and generates a displacement signal
7 indicative of movement of the actuator in a direction generally perpendicular to a
8 longitudinal axis of the actuator; and

9 wherein a sample is coupled to the actuator.

1 47. A method for measuring movement of an actuator in a metrology apparatus,
2 the method comprising:

3 providing an objective mounted on a reference structure coupled to the
4 actuator;

5 measuring movement of the objective, wherein movement of the objective is
6 indicative of movement of the actuator in a direction generally perpendicular to the
7 longitudinal axis of the actuator; and

8 wherein a sample is coupled to the actuator.

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1 48. The method of claim 47, wherein the measuring step further comprises:

2 generating a light beam from a stationary light source;

3 changing the direction of the beam in response to movement of the objective;

4 detecting the location of the beam with a position sensor; and

5 generating a displacement signal indicative of movement of the actuator.